UK Government

# Updating evidence on Energy Efficiency potential for the UK Fuels Sector Including Refineries

March 2026

# Contents

# 1. Executive Summary

The following report outlines estimates of energy efficiency potential in the UK refineries sector until 2050. Fuels Industry UK assisted the Department of Energy Security and Net Zero and liaised with the UK refineries to produce a set of results for energy efficiency (EE) potential consistent with refineries' plans and options to decarbonise in the longer term. In this context, EE is defined as reduction to the delivered energy consumed per unit of production of industrial output.

This report updates the 2015 *Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050*,[1] which considered energy-related levers available to decarbonise industry, including EE, fuel switching and Carbon Capture Storage and Utilisation (CCUS). This research relates to EE measures available within the industrial process only and does not include building level or behavioural EE measures.

The aim of this study was to update estimates out to the year 2050 on:

1. Percentage energy savings the UK refining sector could achieve compared to a baseline projection of the sector's energy consumption.
2. Percentage carbon emissions savings the UK refining sector could achieve compared to a baseline projection of sector's carbon emissions.
3. Aggregate capital expenditure (CapEx) associated with the EE projects that could deliver these savings

These outputs were estimated for two pathway scenarios:

1. Business-as-usual (BAU): describes future deployment of EE projects under an assumption that current investment preferences and criteria are maintained and the policy landscape and economic outlook in which those investments take place also remains unchanged, at the time of the study.
2. Maximum technical potential (MTP): describes future deployment of EE projects under an assumption that all non-technical barriers to its deployment are removed, such as CapEx and planning and permitting barriers.

Information was also gathered to update and augment evidence relating to the barriers to the uptake of the identified EE projects.

For this work, the scope of EE projects under the BAU pathway were identified by refinery experts as those which are planned or likely to take place and were usually identified from 2022 Energy Savings Opportunity Scheme (ESOS) submissions. The scope of EE projects under the MTP pathway included technologies with a technology readiness level of 7 or above and that could be feasibly implemented without non-technical barriers. This work revealed that by 2050 the UK refining sector could reduce energy consumption by 7% under a BAU scenario, saving 7% of carbon emissions. For the MTP scenario, the UK refining sector could

[1] https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

reduce energy consumption 16% by 2050, saving 13% of carbon emissions from the sector. The total estimated CapEx for the BAU pathway was £290 million, with most, according to consultation with refinery experts, being implemented in the nearer term future (before 2035) under current business plans. From the refinery data returns, commonly identified techniques include further process unit optimisation, waste heat recovery for third party use, limited electrification of furnaces and boilers, and further electrification of compressors and other steam turbine drives. Total estimated CapEx for the MTP pathway was £1.4 billion which was more evenly spread across the time period to 2050.

This study was compared to the 2015 “Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050” report which estimated that energy efficiency related measures could achieve BAU emissions savings, on a like-for-like basis, of 12% and MTP savings of 18% by 2050, despite differences in pathway development and analysis.

# 2. Introduction

## 2.1. Background and policy context

Fuels Industry UK were requested by the Department for Energy Security and Net Zero (DESNZ) to contribute to and help with an update to the evidence base related to the potential for industrial energy efficiency (EE) improvements in the United Kingdom's refinery sector. This research builds upon findings on the refinery sector from the 2015 study: 'Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050' and was carried out in parallel with research undertaken by Ricardo Energy & Environment commissioned by DESNZ on potential EE improvements across other industrial sectors.

This project is concerned only with updating the evidence base relating to the potential for EE to reduce carbon dioxide ($CO_2$) emissions in industry. Other decarbonisation levers applying to industry, i.e. CCUS, fuel switching and resource efficiency, are considered separately in other DESNZ publications.

The quantitative results of this work are being used by DESNZ to advise Government on the setting of the 7th Carbon Budget (CB7) which runs from 2038-2042 and future Carbon Budgets. The qualitative results, especially those relating to barriers to and enablers of the deployment of EE measures, are being closely considered by DESNZ in its review of the industrial EE policy landscape.

The UK fuels sector covers a combination of refineries, terminals, and pipelines responsible for supplying 34%[2] of the country's primary energy in 2022 (the reference year for the energy efficiency study with an emissions adjustment discussed in Section 2.4). In its simplest form, an oil refinery converts crude oil into petroleum products as required by the market in the most efficient and profitable manner. Refineries are driven by the production of profitable fuels such as gasoline, kerosene, and diesel, though other products of refining crude oil play key roles in petrochemicals, lubricants, and refinery fuel use.[3] The sector is an important contributor to the UK's economy in addition to ensuring energy security and maintaining stocks and reserves. As an energy intensive industry, the six UK refineries accounted for 10%[4] of industrial emissions covered by the UK Emissions Trading Scheme in 2022, making it a key sector both for decarbonisation and an overall improvement in energy efficiency. It should be noted that one refinery transitioned to import terminal operations only and a second refinery is expected to cease manufacturing operations, both in 2025 – this report models for six refineries, however, this is no longer the case in the UK.

Demand for petroleum products in the UK was 54.8 million tonnes in 2022[1]. This was met through a combination of domestic production and imports by the six UK refineries: EET Stanlow, Esso Fawley, Petroineos Grangemouth, Phillips 66 Humber, Prax Lindsey and Valero

[2] DUKES, Chapter 3 Petroleum, Table 3.1, 2022
[3] Wood Mackenzie, Introduction to Refining, 2024
[4] UK ETS Public Reports, UK ETS Registry Participants and Allocations (OHA), 2024

Pembroke and supply through import terminals. Due to changing fuel demand trends, technical limitations on product yields from refineries and commercial arrangements, UK refinery output does not exactly equal domestic demand. Therefore, the market also sees exports of products, including products where the UK is 'short', which balance supply and demand across the range of petroleum products. Overall, the refinery operators accounted for 89% of products supplied (both domestic manufacture and imports) into the inland market in 2022[1].

Against a backdrop of the government's commitments to Net Zero and a just energy transition, the fuels sector delivers energy security and resilience while still attracting some level of investment in decarbonisation projects, including in a few cases carbon capture and hydrogen production for both its own use and third parties. This can be seen in EET fuels £3 billion investment in HyNet and other energy transition initiatives in North-East England over the coming years[5]. However, maintaining this contribution to Net Zero and a just energy transition will require a good understanding of the barriers to investment and the business environment required to maintain sector competitiveness. Potential energy efficiency improvements depend on individual refinery configurations (the type of and organisation of refinery process units – see glossary) and the need to balance their respective energy usage (energy balance).

In recent years, demand for refined products has decreased, leading to refinery closures and a challenging business environment for refinery operators: between 2015 and 2024, petroleum product demand has decreased by 11%[6]. Despite some challenges, UK refineries have undergone many upgrades during turnaround years (planned periods of regeneration in a refinery) that have increased yields for more profitable products such as kerosene, diesel, and petrol. These upgrades can also include measures for energy efficiency such as steam leak reduction and waste heat recovery, that are routinely part of turnarounds required for maintenance, inspections and upgrades.

## 2.2. Research purpose and research objectives

The aim of this research is to update data and information currently held by Government relating to EE potential in UK industry. The evidence updated relates to those factors which need to be known to quantify the potential for EE to reduce industrial energy consumption and emissions out to 2050 as well as understanding the costs of doing this and the barriers which must be overcome for the quantified potential to be realised.

The research sought new data to inform an updated picture on:

1. The percentage energy savings the UK refining sector could achieve compared to a baseline projection of the sector's energy consumption.
2. The percentage carbon emissions savings the UK refining sector could achieve compared to a baseline projection of the sector's carbon emissions.

[5] EET Fuels News, Essar Energy Transition launches EET Hydrogen Power, 2024
[6] DUKES, Chapter 3.2 Petroleum

3. The aggregate capital expenditure (CapEx) associated with the EE projects that could deliver these savings

These outputs were estimated for two pathway scenarios:

1. Business-as-usual (BAU): describes future deployment of an EE projects under an assumption that current investment preferences and criteria are maintained and the policy landscape in which those investments take place also remains unchanged, at the time of the study.
2. Maximum technical potential (MTP): describes future deployment of EE projects under an assumption that all non-technical barriers to its deployment are removed, such as CapEx and planning and permitting barriers.

Information was also gathered to update and augment evidence relating to the barriers to the uptake of the identified EE measures. This is important as it informs DESNZ of policy interventions that could lead to higher EE measures uptake and also forms the basis for defining EE deployment scenarios based on continued operation of these barriers or alleviation of them.

## 2.3. Research scope and definitions

This report provides an aggregate view of the UK refineries' future projections of energy use and efficiency, to be included as part of the evidence base for the design of future policies and data for the Climate Change Committee's next carbon budget (CB7). The study was limited to the energy efficiency measures applied to the units within the refinery boundaries defined by the Emissions Trading Scheme (ETS) and does not include efficiency measures of separate CHP plants. All energy efficiency measures were compared against a baseline year that was set as 2022, with an adjustment to the emissions made as discussed in Section 2.4. This year was chosen as the most recent year that was relatively unaffected by the impacts of Covid-19 and corresponded with the most recent Energy Savings Opportunity Scheme (ESOS)[7] survey which contains energy efficiency projects and measures.

The scope of this project covers the UK refineries' energy efficiency projects under business-as-usual (BAU) and maximum technical potential (MTP) scenarios. BAU describes the energy efficiency projects that are currently adopted by refineries operations and/or have been identified by refinery experts (see glossary) as planned projects requiring no significant change to the current refinery operations. MTP describes the maximum level of energy efficiency projects that can be implemented in a refinery without limitations of CapEx, planning and permitting, and other non-technical barriers. Refinery experts gave their views on the potential costs and energy savings from the EE projects that could come under the two scenarios. Sources used to inform potential BAU investments include businesses' own energy efficiency plans and the ESOS benchmarking surveys and analysis of Solomon Insights[8]. MTP sources

[7] 2023 Energy Savings Opportunity Scheme Submission – Total energy consumption analysis and energy audit.
[8] Solomon, Refining Benchmarking

focused more on projects identified from the Oil and Gas Climate Initiative (OGCI) White Paper "Powering up: Pathways to decarbonize refining"[9] with a Technical Readiness Level (TRL) of 7 and above.

For the purpose of this work, which was to estimate the aggregate impacts of Energy Efficiency projects only, projects that were considered fuel switching or deep decarbonisation were excluded from the refinery returns in this research. This meant that the energy changes and/or $CO_2$ emissions associated with these projects were not carried through into the aggregated BAU and MTP EE savings. Decarbonisation projects are accounted for elsewhere in the DESNZ industrial decarbonisation modelling and thus were not included in this data gathering project to avoid double counting.

It emerged in the one-to-one discussions, that refineries chose to log some projects that were considered fuel switching/decarbonisation that would make some energy efficiency projects redundant, for example waste heat could be used for Carbon Capture Utilisation and Storage (CCUS). This led to the separation of those projects relating to fuel switching and those relating to deep decarbonisation. This mitigated the risks of double counting or overstating energy savings from energy efficiency measures. This dataset focuses on potential EE measures, excluding projects which are primarily designed to deliver decarbonisation through fuel switching including electrification, hydrogen ($H_2$) and the application of CCUS, and accounting for the deployment of EE measures that might be superseded by these decarbonisation options.

## 2.4. Refinery Main Categories of Energy Use

Energy used in refineries is derived largely from refinery fuel gas (RFG) which is produced as off-gases from refinery processes and is used to fuel furnaces and boilers as a more cost-effective option than natural gas. In addition to internal RFG use, refineries also import natural gas and burn coke produced as a by-product of certain operations to meet their energy needs. Refineries also use heat and electricity from cogeneration facilities and have grid connections for electricity imports and exports.[10]

Data on energy and emissions for the UK refining sector in 2022 were used to inform respective baselines to then calculate the percentage energy and emission savings. The emissions baseline were adjusted to account for the additional emissions from a new diesel hydroprocessing plant in 2025. Assumed changes in refinery throughput over time were used to scale the projected baseline emissions and energy consumption out to 2050.

[9] OGCI White Paper, "Powering up: Pathways to decarbonize refining", October 2023
[10] DECC and DBIS, Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 – Oil Refining, 2015

## 2.5. Energy Measures

The energy efficiency measures that were considered in this project are presented in Table 3 of Annex B. These measures can broadly be assigned to the following categories: electronic drives, steam leaks, flare gas recovery, fractionation improvements, and advanced control techniques. These measures solely aim to improve energy efficiency and are not considered deep decarbonisation techniques.

# 3. Methodology

The information for this research was collected from representatives of UK refineries regarding EE measures the sector would potentially implement under a MTP and BAU scenario, and the associated energy savings and CapEx from these measures. The data was then analysed by the Fuels Industry UK team to inform follow-up engagement with stakeholders to quality assure returns before aggregating the data into a comprehensive dataset to produce an understanding of the potential EE savings for the sector out to 2050. The following sections detail the methodology behind this data collection and analysis in detail.

## 3.1. Initial Data Request

Following engagement and agreement with DESNZ, an Excel template developed by Fuels Industry UK was sent out to refinery experts (see Annex A) with detailed instructions for filling in the worksheets. The following section provides a summary of the steps carried out by the refinery experts.

### 3.1.1. Identifying Business-as-Usual and Maximum Technical Potential projects

Energy efficiency projects identified by refinery experts as planned or feasible were inputted with a short description, implementation date, and quantitative data on $CO_2$ emissions reductions and/or changes in energy consumption by fuel source. These projects were often located within the 2023 Energy Savings Opportunity Scheme (ESOS) submission, which included short-term and long-term projects with CapEx estimates. Other sources of data for projects are referenced[11,12,13,14,15] and/or derived by the refinery experts' understanding of the refinery operations and upcoming plans. The quantitative data was summed together to give the emissions and energy changes in 5-year intervals from 2025 to 2050. The start year for when savings commence are from 2024 as this is when the research was conducted.

The MTP projects were identified by the refinery experts as EE measures that would technically be possible to implement, discarding non-technical barriers such as high CapEx or poor cost-effectiveness. In some cases, there was overlap between BAU projects and MTP techniques, however, implementation of some MTP techniques changed the timeline or feasibility of BAU projects. For example, improving waste heat recovery projects may not be

[11] European IPPC Bureau, BREF Document, "Refining of Mineral Oil and Gas", February 2015
[12] OECD NEA, "Small Modular Reactors", 2021
[13] International Atomic Energy Agency, "Small Modular Reactors: A new nuclear energy paradigm", 2023
[14] Concawe, "EU refinery energy systems and efficiency", Report no. 3/12, 2012
[15] Concawe, "$CO_2$ reduction technologies. Opportunities within the EU refining system" (2030/2050), Report no. 8/19

necessary if the process unit is electrified. This meant that the BAU and MTP, therefore, formed separate pathways.

### 3.1.2. Calculating BAU and MTP energy and emission savings

Development of both BAU and MTP energy and emissions savings has been undertaken through the following steps:

i) Development of a baseline for energy consumed and carbon emissions

Data for the baseline year, 2022, was compiled with total energy, also considering imports and exports, converted to MWh[16]. Fuels Industry UK member companies also provided $CO_2$ (by UK ETS definition, not $CO_2e$) emissions information, taking co-located power generation into account. Throughput projections from the UK refining sector used for this work were assumed to remain constant due to constraints imposed by competition law. Due to pre-planned, ongoing or potential projects until 2030 (BAU) and 2035 (MTP) the energy demand and emissions remain constant after the respective year.

ii) Aggregation of data

The data from the individual refineries' returns was aggregated to sum the total value of the energy and emission savings from EE projects for the 5-year intervals from 2025. The required CapEx for EE projects were summed across all refineries. The net energy demand was calculated from the aggregated data and compared against the individual refinery returns to ensure the outputs were consistent.

iii) 'Implementing' projects against the baseline

For the subsequent time intervals, the aggregated data from the summary table of BAU and MTP projects were either added or subtracted from the corresponding fuel type (or $CO_2$ emissions) baseline year to reflect how the implementation of the identified projects affected the total energy demand and the $CO_2$ emissions.

iv) Assessment of impact

To calculate the proportion of potential energy savings under the BAU and MTP scenario the aggregate energy savings were compared to an energy baseline for refining sector out to 2050 which was based on the 2022 baseline data with the adjustment to emissions from a new diesel hydroprocessing plant, as discussed in Section 2.4.

The proportion of emission savings from EE measures under the two scenarios was also calculated against an equivalent emissions baseline ('Main Categories of Energy Use' section). By calculating a proportion of energy and emission savings this research provides outputs that can be applied to future energy consumption and carbon emission baselines for the refinery

[16] Department of Energy Security and Net Zero, GHG Conversion Factors for Company Reporting, 2022

sector which will be subject to change, influenced by factors such as throughput levels and implementation of decarbonisation plans.

## 3.2. One-to-one Meetings and Quality Assurance

After the initial data returns, the data was analysed by the Fuels Industry UK team (see Annex A) to look for inconsistencies and anomalies based on their combined industry experience. Refinery returns were compared against public data and nameplate capacities as a sense check for the real values.

Taking account of company specific confidentiality, a series of one-to-one calls were set up with members of the Fuels Industry UK team and the refinery experts (from the corresponding six UK refineries) to validate the data and resolve any queries. These one-to-one calls were informally structured and tailored to individual returns as each refinery expert had their own set of questions and each initial return was varied in completeness.

The calls allowed the Fuels Industry UK team to understand the origins of the data and rationale of projects, providing consistency across the returns. Fuels Industry UK used the background and expertise of the team (Director of Special Projects and Energy Transition Lead) to sense check the values and projects and discuss potential barriers to implementing EE measures faced by refineries.

# 4. Results

This research aimed to define UK refineries energy efficiency potential from present day to 2050. The results of this data collection show the energy changes in 5-year periods from the baseline year giving a profile of the EE potential in this sector. The results are split into the two defined scenarios: BAU and MTP, showing by energy consumption the differences in the two scenarios. $CO_2$ emissions of the refineries were reported for both scenarios and show how refinery emissions will change with the implementation of energy efficiency measures.

**Table 1: BAU Results Pathway**

| UK Refineries: AGGREGATE | Unit | Baseline (2022) | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| Change Net Energy Demand 2050-baseline* | % | 0.0% | -0.7% | -5.5% | -7.0% | -7.0% | -7.0% | -7.0% |
| Change Net Emission 2050-baseline* | % | 0.0% | 0.0% | -6.1% | -6.6% | -6.6% | -6.6% | -6.6% |

**Table 2: MTP Results Pathway**

| UK Refineries: AGGREGATE | Unit | Baseline (2022) | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| Change Net Energy Demand 2050-baseline* | % | 0.0% | -1.1% | -8.7% | -13.7% | -16.0% | -16.1% | -16.2% |
| Change Net Emission 2050-baseline* | % | 0.0% | -0.5% | -8.0% | -11.9% | -13.0% | -13.1% | -13.2% |

*Note: Scaled to throughput*

**Figure 1: Percentage of BAU and MTP Total Energy Demand savings compared to an energy baseline for the UK refineries sector (indexed, 100=2022)**

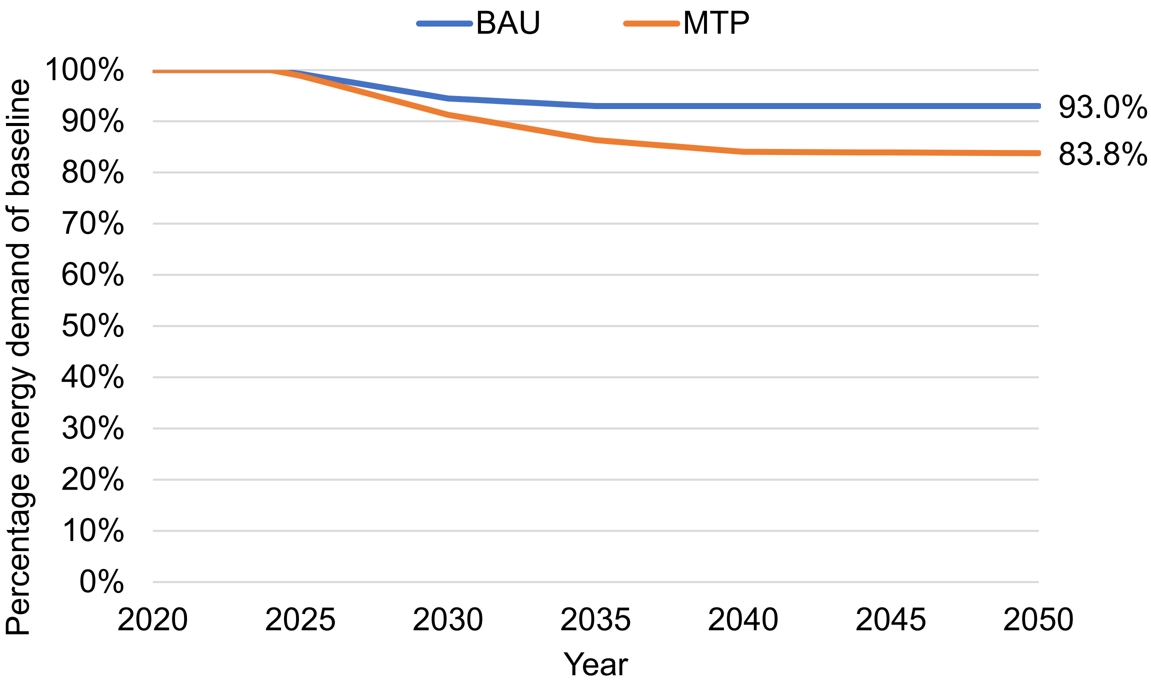
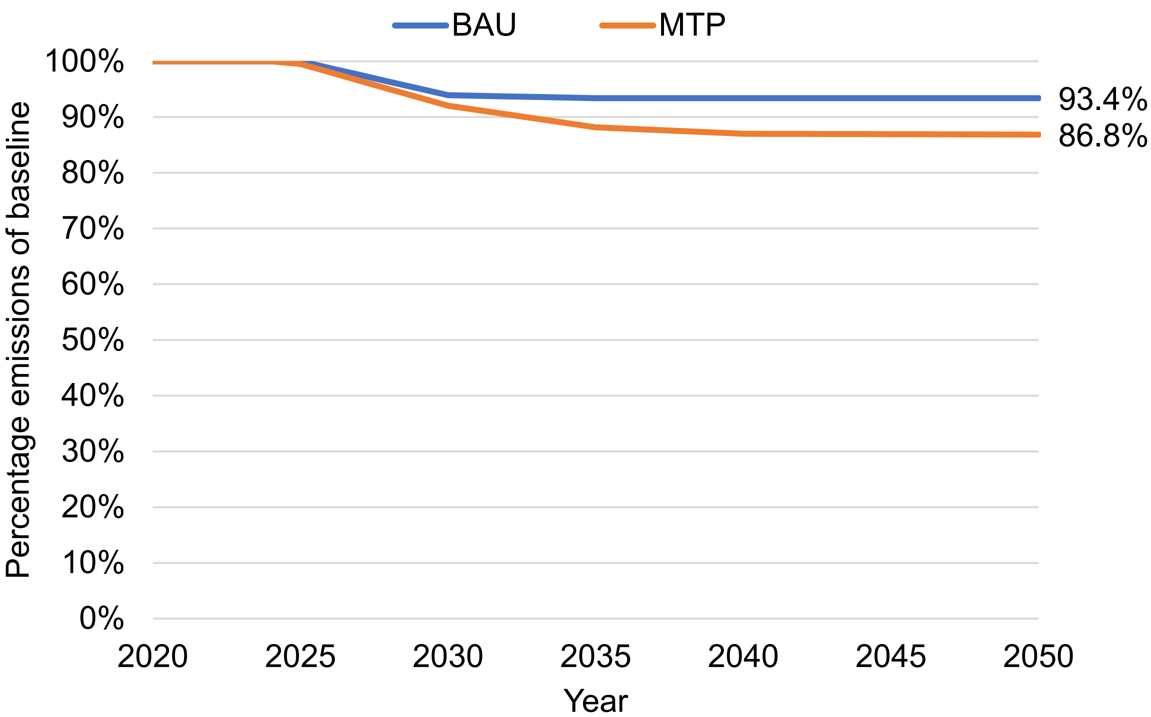



**Figure 2: Percentage of BAU and MTP Total Net $CO_2$ Emissions savings compared to an emissions baseline for the UK refineries sector (indexed, 100=2022)**



Business-as-usual (BAU) results (Table 1) showed a 7% reduction in total net energy demand between the 2022 base year and 2050. $CO_2$ emissions are expected to fall by almost 7% between 2022 and 2050. The adjustment to the emissions in 2022 to account for additional emissions in 2025 from a new diesel hydroprocessing unit were in proportion to the throughput for the baseline case. This project increases $CO_2$ emissions, until it can be linked with CCS in the future. The results are an aggregation of the 6 UK refineries in scope for the project.

From the engagement with refinery experts on behalf of the UK refining sites, broad trends across the refineries in achieving improved energy efficiency were recognised and discussed. These trends covered using technologies such as improved furnace efficiency, process unit optimisation, flare gas recovery, and replacement of steam turbines with electric drives.

The total estimated CapEx for these projects was £290 million, with most being implemented in the nearer future (before 2035) under current business plans.

The Maximum Technical Potential (MTP) pathway showed over a 16% decrease in total net energy demand from the 2022 baseline to 2050. In addition, $CO_2$ emissions were reduced by about 13% in 2050 from the adjusted 2022 baseline levels. From the refinery data returns, commonly identified techniques include further process unit optimisation, waste heat recovery for third party use, limited electrification of furnaces and boilers, and further electrification of compressors and other steam turbine drives. The CapEx estimate for MTP pathway was £1.4 billion which was more evenly spread across the time period to 2050.

It is important to note that not all projects identified in the BAU pathways made up the MTP pathways. For refineries, in some cases, more CapEx intensive projects with greater energy savings in the MTP made BAU projects redundant, e.g. heat loss efficiency projects were not considered if a larger waste heat project could be implemented in MTP. This means that the MTP pathway does not represent a further 9% energy saving on top of the BAU scenario, but a different pathway towards greater energy efficiency.

# 5. Barriers to Energy Efficiency

This section aims to set out some of the challenges to implement EE measures and undertake wider decarbonisation that refineries in the UK are facing. Section 5.3 then compares this update to the results published in the 2015 “Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050.

From the pathways described in Section 4 and the quality assurance discussions between Fuels Industry UK and the six refinery experts, a number of factors were considered as barriers to implementation of these energy efficiency measures. These barriers fell into two categories of technical and non-technical. Technical barriers encompass limitations of energy measures due to material challenges, e.g. electricity supply. Non-technical barriers are barriers from non-material challenges, e.g. planning and permitting. This discussion emphasises the significance of the technical and non-technical barriers on the implementation of current and future energy efficiency measures and aims to provide clarity on how the policy and regulatory environment give rise to these barriers.

## 5.1. Technical Barriers

One of the largest technical barriers to improving efficiencies in both BAU and MTP cases is the production and resultant necessary use of refinery fuel gas (RFG). RFG is a byproduct of refinery processes so the use of potential surplus RFG from improving energy efficiency must be considered. Separating RFG further to produce marketable products (e.g. LPG) is not financially viable and burning or “flaring” is not allowed in the UK under existing permit rules due to the noise, light and $CO_2$ pollution that would result[17]. Given these restrictions and the high energy content of RFG, refineries therefore use RFG as a partial replacement for natural gas demand, although in general both are used together with natural gas as the ‘balancing fuel’ for all six refineries[18]. RFG may also be used alongside hydrogen in future given the expected role for that gas in industrial decarbonisation. Ultimately, natural gas consumption can be reduced to zero, but the RFG produced must be used to avoid flaring which would result in higher $CO_2$ emissions. As such, there is little scope for pure electrification at refineries owing to the necessary production and use of RFG.

Steam production is another large technical barrier. Steam is produced by the combustion of RFG and natural gas in boilers. While electrification of turbine drives can remove the need for steam, and therefore reduce $CO_2$ emissions, this is impractical. As discussed above, it is critical that RFG needs to be combusted, either in utilities or through flaring and the most effective route overall is for this to be used in utilities production. Therefore, total electrification

[17] IEA, Gas Flaring, https://www.iea.org/energy-system/fossil-fuels/gas-flaring
[18] A balancing fuel makes up any shortfall between the energy required by refinery fuel gas production and the overall refinery energy requirement.

of turbines and drives and removal of any steam production is not a feasible option for refineries.

Another factor to consider is the role of petroleum coke in refineries. Petroleum coke is formed on the catalyst used in fluid catalytic cracking units as a routine part of the production process and burnt off during the catalyst regeneration process, with the energy produced recovered.[19] As such, this form of petroleum coke cannot be recovered as a marketable product. This process relates strongly to emissions but also plays a role in EE projects in a similar manner to RFG since catalytic regeneration is critical and energy recovery processes (steam production) are already in place.

Another technical barrier for both the BAU and MTP scenarios is the need for new electricity supply. Both pathways indicate that electrification could be a method to drive energy efficiency improvements and reduce carbon emissions, but this requires a reliable supply of low carbon power from the electricity grid and may need further development of grid connections, with the associated lead times.

In the MTP case, the absence of a waste heat market and the cost of retrofitting waste heat distribution was identified as a technical barrier. Recent designs for energy efficiency have exposed significant capital expenditure to retrofit and long project schedules of up to 4 years[9].

## 5.2. Non-Technical Barriers

Fuels Industry UK have also determined a number of non-technical barriers to the BAU and MTP pathways.

A significant barrier to energy efficiency projects is the policy and market uncertainty. With current oil demand decreasing and a challenging business environment, the sector is limited in its ability to invest in decarbonisation and/or energy efficiency technologies. Furthermore, technologies that have longer payback periods or are more technically demanding are less likely to attract investment without a clearer understanding of the industry’s future and support from government.

Planning and permitting was also considered a major barrier for implementation of projects, which was echoed during the conversations in one-to-one calls with refinery experts. The process for submitting an environmental permit application and securing the result of the planning decision (determination) can be lengthy. For example, one single carbon capture permit application has taken three years to prepare, and for its status to progress to “duly made” (see glossary). It is likely to take a further 12-24 months for the determination of the application. Obtaining an environmental project permit determination (required to start

[19] SULZER, Fluid Catalytic Cracker (FCC), https://www.sulzer.com/en/shared/applications/fluid-catalytic-cracking-fcc

operations) is essential to reducing project risk and therefore providing certainty for the investment decisions.

Furthermore, regulator guidance on setting permit conditions for new technologies is sometimes perceived by operators and investors as disproportionate, which in some cases, increases project risks and costs:

1. Permitting guidance specifies a minimum capture rate of 95% in contrast with the DESNZ Industrial Carbon Capture, Utilisation and Storage (ICCUS) business model that requires an 85% minimum. Operators will strive to achieve high capture rates to optimise economics under the business model because there is an ETS-driven incentive to do so.
2. Full disclosure of solvent composition is required which discourages use of proprietary solvents that offer higher efficiency or have other benefits.

- A number of knock-on effects are inevitable with deployment of new technologies - increased noise, water use, and effluent pollutant levels. The zero-change approach adopted by the regulators is disproportionate and would not apply to a new standalone plant.

Other identified non-technical barriers are as follows:

1. International companies may have more attractive opportunities elsewhere, e.g. U.S., Europe, where there is cheaper carbon pricing and/or lower labour costs[9,20]. All UK refinery operators are part of businesses with interests in other countries and their project proposals also compete for capital against projects or new business opportunities elsewhere, which may have a better return on investment or higher strategic priority. Therefore, even though identified as possible projects, these may not be undertaken due to other opportunities or priorities.
2. Absence of a Carbon Border Adjustment Mechanism (CBAM) means lower carbon intensity products manufactured in the UK cannot compete in a fair way in both domestic and export markets.
3. High grid electricity[21] and gas costs, and other costs lead to challenging project economics; supply chain issues including availability of electrolysers, pressure vessels, and high-grade steel.
4. Skills and workforce availability[22]. New technologies require a skilled and knowledgeable workforce for effective implementation. Many refineries experience a shortage of personnel, that are spread across managing the extensive planning and permitting tasks and carrying out the energy efficiency projects.

[20] Ember Energy, European electricity prices and costs, 2022
[21] UK Parliament, House of Commons Library, Domestic Energy Prices, 2024
[22] Cogent Skills and Fuels Industry UK, Future skills for the downstream sector, 2022

## 5.3. Comparison to 2015 Study

The process to deliver this report varies from the pathways development and analysis undertaken for 2015's "Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050". Most notably due to updated views on the potential deployment of deep decarbonisation technologies, such as carbon capture and low-carbon hydrogen for refineries, which can impact the level of investment in EE projects. This study has focussed solely on EE measures, whereas the 2015 report covered a wider range of technologies that reduce $CO_2$ emissions. A significant difference from the 2015 assessment is due to the updated baseline of the sector (2022 versus 2012) and the simplified assessment by removing multiple scenarios and focusing the number of technology options in scope. Despite the differences, carbon emissions savings modelled in each report are similar when adjusted to compare like-for-like technologies only[23]. Analysis in the 2015 report suggested that by 2050 EE projects have a potential saving of 12% in the BAU scenario and 18% in the MTP scenario.

[23] Both studies have included the following technologies: steam utilities optimisation, process heaters and furnaces, advanced control and monitoring, pumps compressors and fans, and waste heat recovery.

# 6. Limitations of the Research

It is important to acknowledge the limitations of the project and consider their effects on the interpretation of the outcomes.

A primary limitation of this research is that the pathways are long term estimates of potential project activity, they are not forecasts or commitments. The near-term estimates, which are made for the next 3 years, are often based on business planning assumptions which may be subject to change. Beyond this time horizon the level of uncertainty around EE improvements are high due to potential changes in economic and technological factors that may impact business decisions over time. The impact of this on the energy efficiency pathways leads to the true energy efficiency pathways being either greater or smaller than described in this study.

Additionally, the timelines are indicative and may vary from project to project, for example implementation dates and rollout time are likely to have high uncertainty. Thus, the profiles of the energy efficiency pathways may differ from the profiles shown in Figures 1 and 2 in Section 4. For example, a continual (linear interpolation) approach has been modelled, but in reality new projects coming online will result in stepwise changes.

Another important limitation is the assumption of a flat throughput for all refinery projections, due to constraints imposed by competition law restricting the collection of future throughput data, therefore this was assumed to be flat and does not include turnaround years where refinery throughput is often reduced. It is understood that the energy consumption of a refinery is affected by the refinery throughput, therefore changes to the refinery throughput would change the estimations of energy efficiency potential. The percentage energy and emission savings that could be possible under a BAU and MTP scenario presented in this report could be assumed applicable to alternative throughput projections which is why the report focuses on the percentage savings rather than absolute emission and energy savings.

# 7. Conclusion

Based on the information found in this project, Fuels Industry UK and DESNZ were successfully able to estimate refineries energy efficiency pathways under BAU and MTP scenarios. The BAU scenario would require a £290 million CapEx investment achieving a 7% reduction in both energy demand and $CO_2$ emissions. The MTP scenario would require a five-fold increase in CapEx compared to the BAU scenario, at £1.4 billion, and would achieve a 16% and 13% reduction in energy demand and $CO_2$ emissions, respectively.

The one-to-one quality assurance discussions with the individual refinery experts, helped piece together an understanding of the barriers to energy efficiency faced by the refining industry. The refining sector operates with low margins thus CapEx for investment is less available, despite this energy efficiency has been ongoing at UK refineries during turnaround years and with some new technology. Furthermore, there are external challenges for UK refineries, such as declining domestic demand and relatively high energy costs, which have been linked to refinery closures and may make obtaining investment more challenging. A key takeaway are the non-technical barriers that limit refinery energy efficiency projects. Enabling a stable policy environment that encourages investment in energy efficiency projects, could see significant impacts on the level of energy reduction potential. Additionally, $H_2$ and CCUS projects are under way with investment from UK refineries as they are widely considered by the UK refining industry as the next big step for energy efficiency and decarbonisation.

# 8. Glossary

BAU – Business-As-Usual: The scope of energy efficiency projects that are currently being adopted by refineries operations and/or have been identified by refinery experts as planned projects. These were usually identified in their 2022 ESOS submission.

Duly made – Status for when a permitting application is in the public domain and the planning authority must adhere to a set timeline to make their decision.

MTP – Maximum Technical Potential: The maximum feasible (TRL 7 or above) level of energy efficiency projects that can be implemented in a refinery without limitations of CapEx, planning and permitting, and other non-technical barriers.

Non-technical Barrier – barriers from non-material challenges, e.g. planning and permitting.

Payback period – the length of time for an investment to recover its initial outlay in terms of profits or savings.

Refinery configuration – The units used to produce a range of petroleum products and the arrangement of said units. These configurations are typically based on the source of crude slate and aim to maximise the production of the most profitable products, thus are rarely the same.

Refinery Energy Balance – Tracks the flow of energy from the demand of refinery activity, through transformation stages to waste energy or exported energy. Energy consumption monitoring is widely practised by refiners and energy balances are produced regularly, even daily.

Refinery Expert – Company refinery experts (economists and strategy leads) were nominated by corresponding Fuels Industry UK Council Members to lead on completing the data request and participating in 1-2-1 quality assurance calls.

SIC – Standard Industrial Classification Code: Identifies the type of economic activity a business is involved in.

Technical Barrier – limitations of energy measures due to material challenges, e.g. electricity supply.

TRL – Technical Readiness Level: A type of measurement system used to assess the maturity level of a particular technology. Ranging from TRL 1 (basic principles observed and reported) to TRL 9 (actual technology qualified through successful mission operations).

# 9. Annex A – Notes on Methodology

Refinery Expert – Company refinery experts (economists and strategy leads) were nominated by corresponding Fuels Industry UK Council Members, in the following companies:

- EET Fuels (Stanlow)
- ExxonMobil (Fawley)
- P66 (Humber)
- Prax (Lindsey)
- Valero (Pembroke)
- Petroineos (Grangemouth)

Fuels Industry UK Team that undertook data gathering, review, challenge and aggregation of refinery information, and who presented the results were as follows:

- Peter Webb – Policy Director
- Andy Roberts – Director of Special Projects
- Chris Gould – Energy Transition Lead
- Jen Black – Energy Transition Analyst
- Daniel Greenblatt – Energy Transition Analyst

# 10. Annex B – Energy Efficiency Measures

The Energy Efficiency measures that Fuels Industry UK used to structure our analysis include the following, these were stated the template that was shared with refinery experts under BAU projects.

**Table 3: Energy Efficiency Measures Used by Fuels Industry UK to Structure their Analysis**

| Measure | Definition | Applied Equipment |
|---|---|---|
| Electric boiler (dynamic combustion chamber) | Generates steam via direct combustion of hydrogen in a boiler system. | All steam production via boilers |
| Electric boiler (electrode) | Complete replacement for fuel-fired steam boilers | All steam production via boilers |
| Electric drives | Alternative to steam turbines to provide shaft power to pumps and compressors. | All steam turbine shaft drivers |
| Advanced process control to optimise energy use | | Site wide |
| Electric furnace (high temperature) | Alternative to heat powered furnaces | Steam methane reformer |
| Electric heat tracing | Optimise flow efficiency in pipes by maintaining temperature control | Site wide |
| Electric heater (large residue) | Replace large residue heaters that are high duty and susceptible to coke formation | VDU, CDU, Coker Charge Heaters |

| | | |
|---|---|---|
| Electric heater (mechanical vapour recompression) | Eliminates of the large amounts of heat wasted via air coolers or cooling water exchangers in the column overheads | Reboilers associated with columns with close boiling point range such as propylene splitter |
| Electric process heater (single phase) | Bundle of shell tube exchanger is replaced with more energy efficient electrical elements | FCC Gasoline Hydrotreater<br>Diolefin Reactor Heater<br>Isomerisation Reactor Heater<br>Naphtha Reformer Heaters<br>Alkylation Unit Air Preheaters<br>MTBE Feed Preheater |
| Electric process heater (tank heating) | Replace steam heating coils | All tanks currently heated by steam coils, sulphur storage heating |
| Energy recovery - power expanders | | |
| Flare gas recovery | Captures flare gases and redirects them into production workflows | All flares |
| Heat exchanger efficiency improvement - fouling control | Reduces refinery fouling which increases efficiency | All heat exchangers |
| Heat exchanger efficiency improvement - new internals | | All heat exchangers |
| Heat pump (<150ºC) | Heat recovery equipment that transforms low-quality heat to higher and more usable heat. | Waste heat recovery for preheating |
| Heat pump (150-230ºC) | Heat recovery equipment that transforms low-quality heat to higher and more usable heat. | Waste heat recovery for processing heat |

| | | |
|---|---|---|
| Hydraulic system optimisation | Control power usage and recover energy | |
| Improved air pre-heating | | |
| Improved furnace efficiency | | All fired heaters |
| Improved heat integration | | |
| Installation of waste heat boilers for fired heaters | | All fired heaters |
| LED lighting | | |
| Minimisation of heat losses by thermal radiation | | Site wide |
| Pinch analysis | Systemic technique for analysing and optimising heat flow | All process units |
| Process unit re-optimisation | | |
| Replacement of steam injector nozzles | Reduces loss of steam | Crude distillation unit (CDU)/vacuum distillation unit (VDU) |
| Replacement of steam injectors by vacuum pumps | Reduces loss of steam | CDU/VDU |
| Steam leak reduction | | Site wide |
| Steam supply rebalancing | | Site wide |
| Waste heat recovery for off-site use | | Fin fan coolers |

| | | |
|---|---|---|
| Waste heat recovery for on-site use | | Fin fan coolers |
| Zero flaring start-up | Reduces loss of flared gases | All flares |

Source:
1. European IPPC Bureau, BREF Document, "Refining of Mineral Oil and Gas", February 2015
2. OECD NEA, "Small Modular Reactors", 2021
3. International Atomic Energy Agency, "Small Modular Reactors: A new nuclear energy paradigm", 2023
4. Concawe, "EU refinery energy systems and efficiency", Report no. 3/12, 2012
5.Concawe, "$CO_2$ reduction technologies. Opportunities within the EU refining system" (2030/2050), Report no. 8/19

This publication is available from: www.gov.uk/government/publications/updating-evidence-on-energy-efficiency-potential-for-uk-industry

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